

Climate Change and Agriculture: Trends and Bi-Directional Impacts



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Outline

- Background
 - Trends in Agricultural Climate Statistics
 - Processes
 - Temperature
 - Phenology
 - Dormancy
 - Extreme Events
 - Elevated CO₂
 - Water Use
 - Land Use
- Case Studies
 - Winter Chill Trends in Fruit Growing Region of CA
 - Impacts of Summer Temperature Extremes on Crop Water Use and Fruit Temperatures

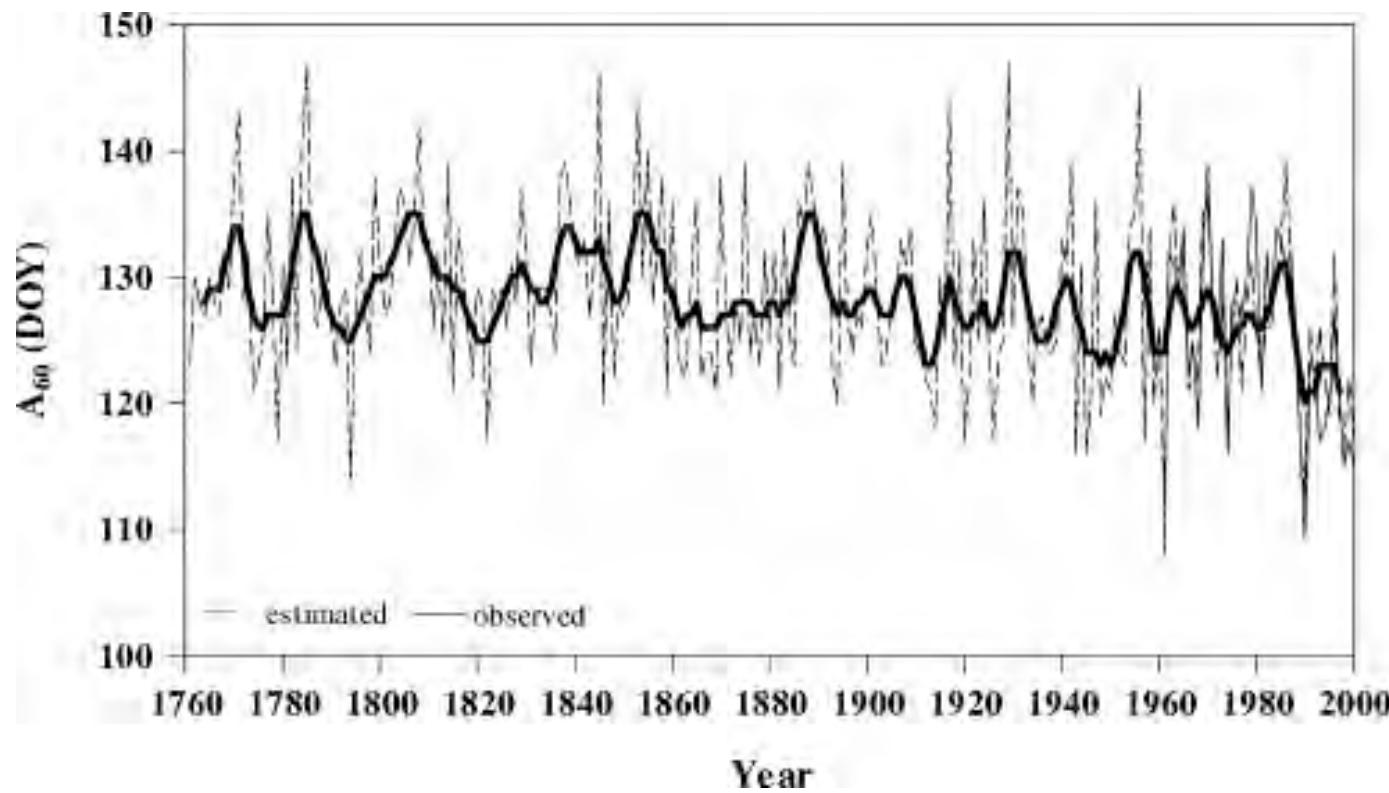


Climatic and Environmental Variables and Statistics affecting Agriculture

- Agricultural Temperature
 - First and Last Frost
 - Length of Growing Season
 - Summed cold units
 - Dormancy
 - Summed Heat Units
 - Phenology, Growth and Fruit Production
 - Extreme Temperature
 - Fruit and Leaf Damage
- Water Supply
 - Rainfall and Irrigation
 - amount, duration, frequency
- Sunlight
 - Amount
 - Growth, Evaporation, Leaf Temperature
 - Diffuse/Direct Fraction
 - Canopy Photosynthesis Efficiency
- Atmospheric Humidity Deficits
 - Evaporative Demand
 - Insect and Microbial Pests
- CO₂
 - Regulates Photosynthesis, Stomatal Regulation, Transpiration
- Pollution
 - ozone

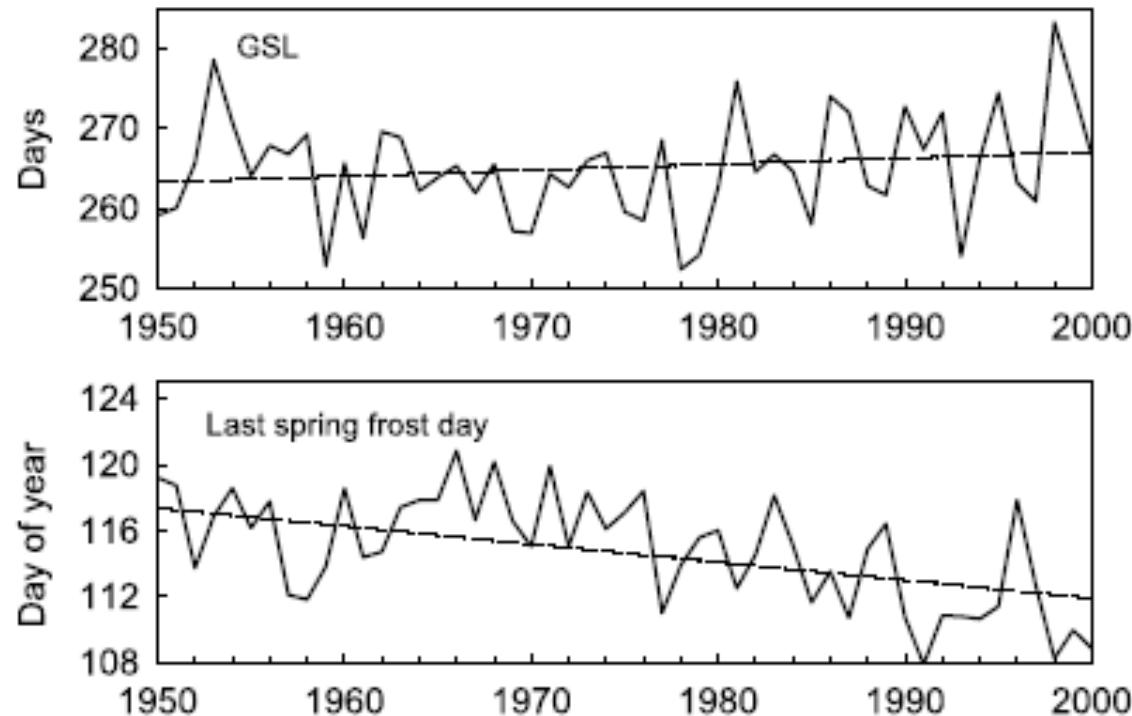


Trends in Phenology, Observed WorldWide



Timing of Apple blossom blooming in Germany

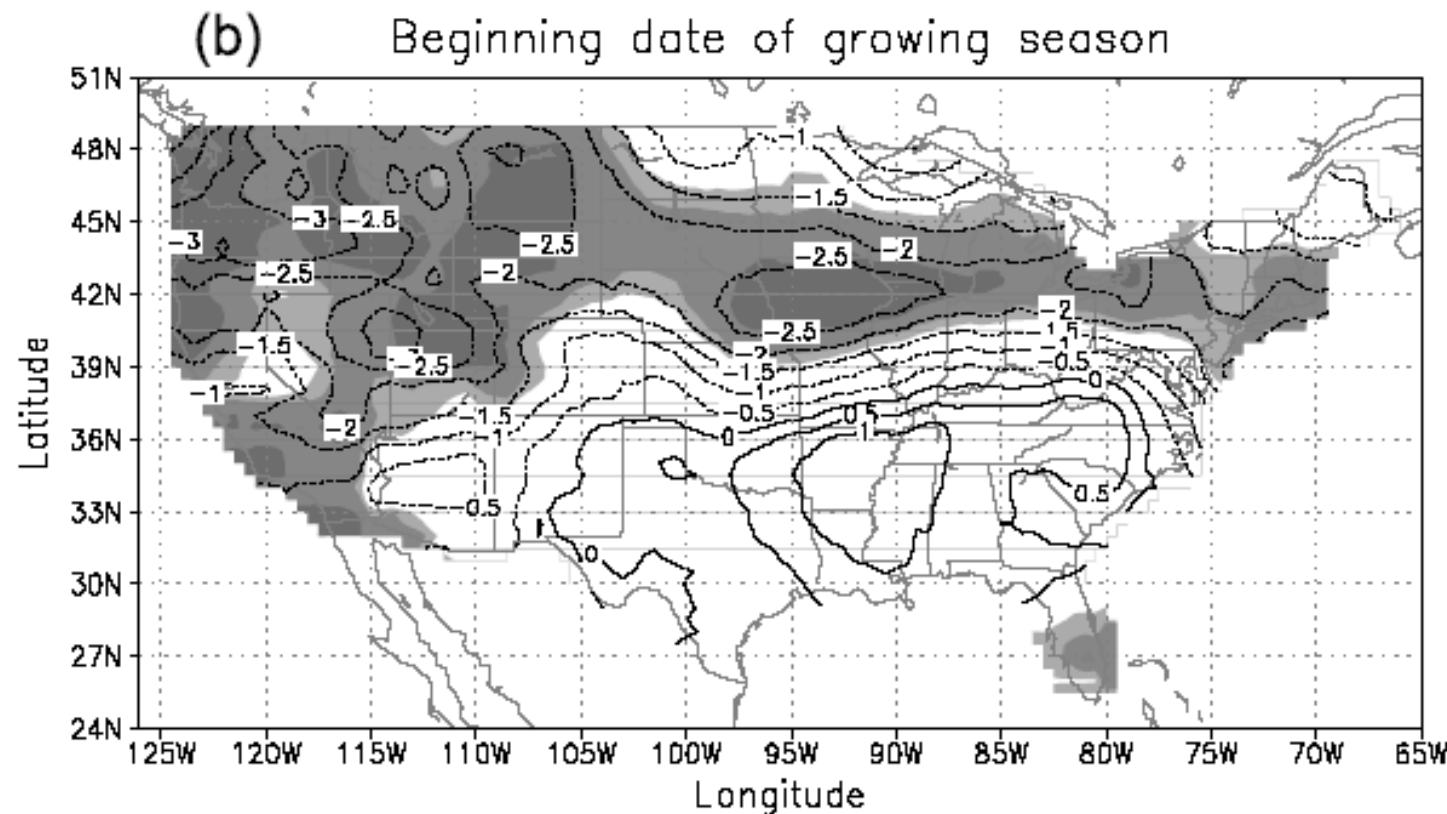
Trends in Growing Season Length and Last Frost Date



Feng and Hu, 2004, J Theor Appl Clim

United States

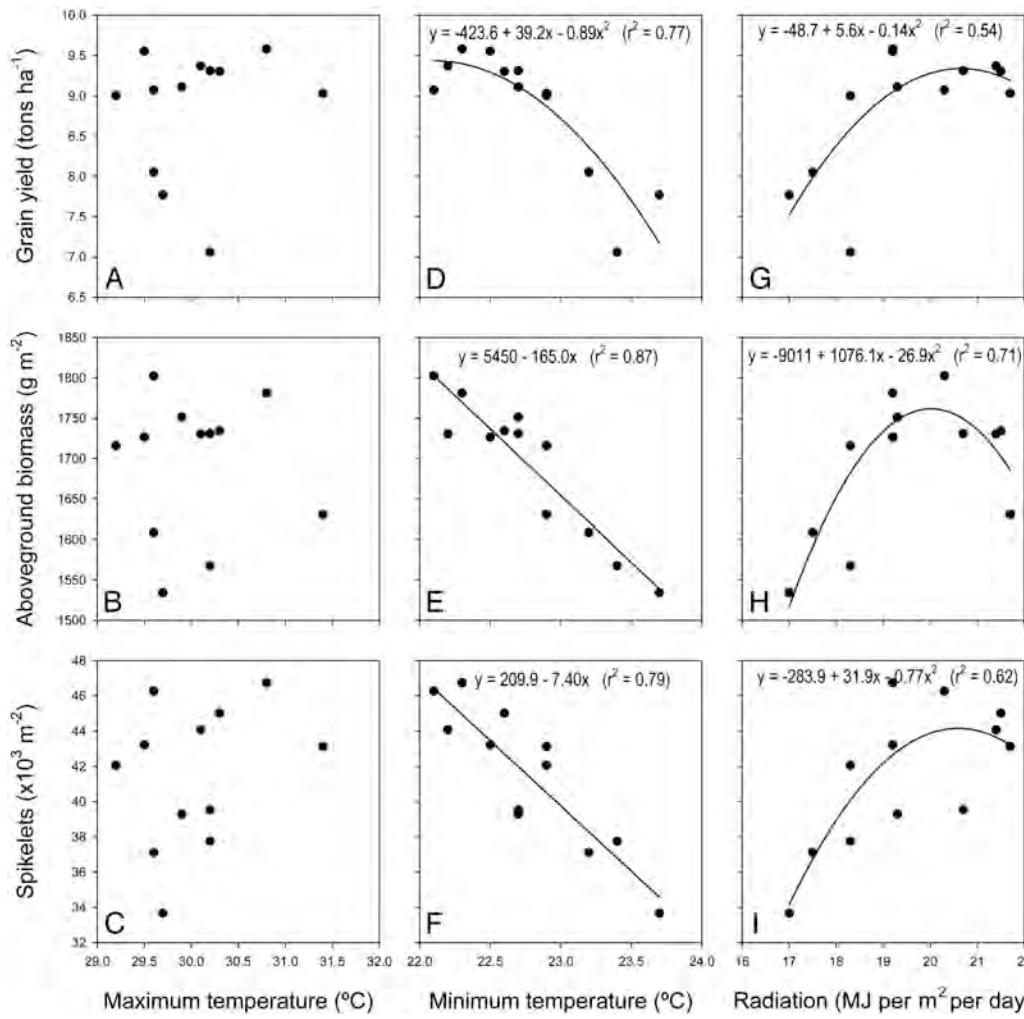
Trend in CA, ~ Growing Season Starts ~1 day Sooner per Decade



Trends, days per Decade

Role of Temperature Extremes on Rice

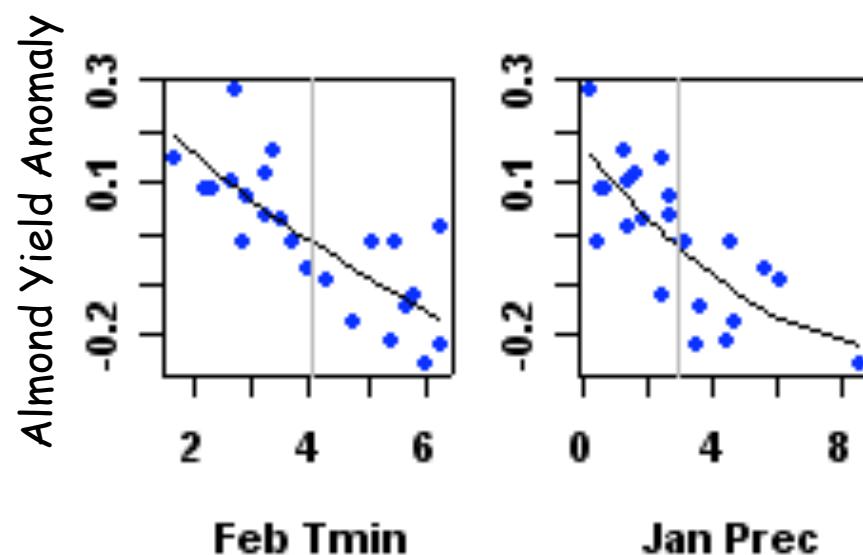
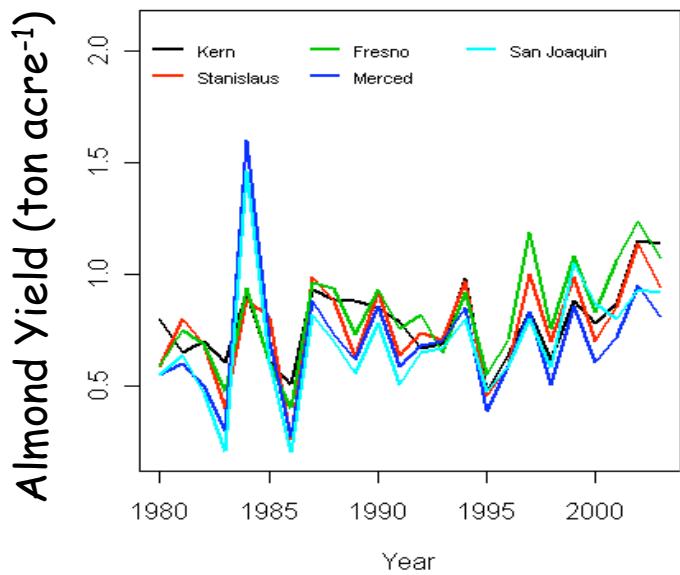
Grain Yield



Spikelets

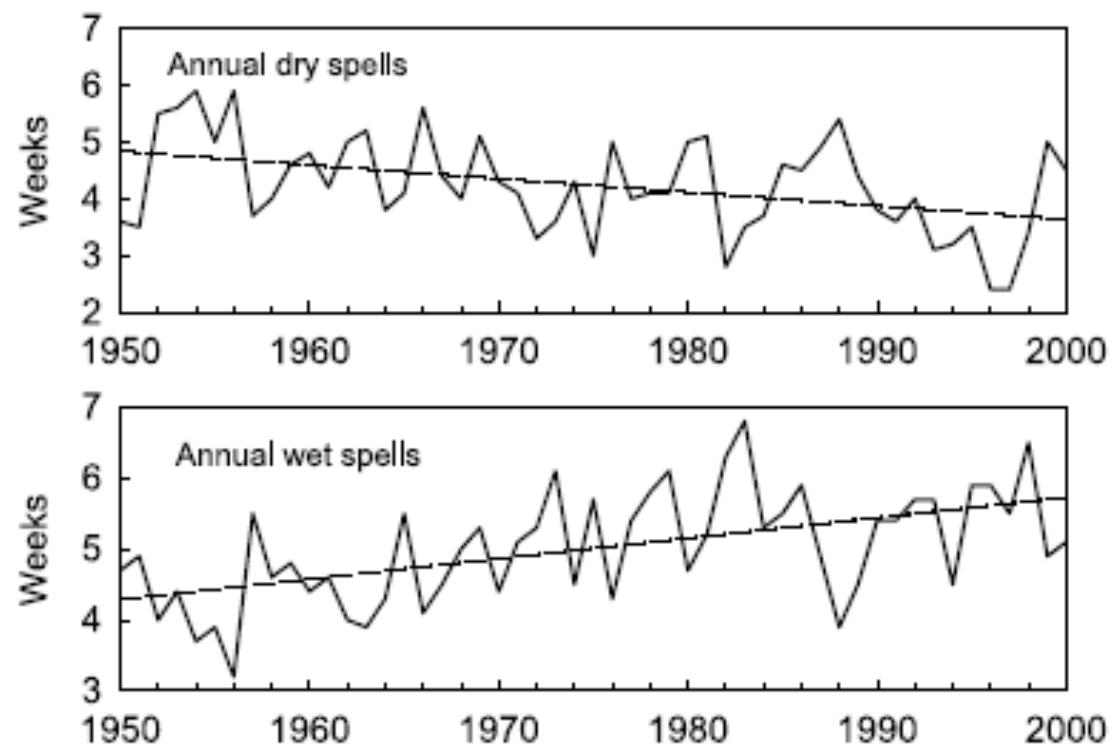
Peng et al PNAS, 2003

Role of Seasonal Statistics and Combination of Temperature and Rain



David Lobell, Unpublished, Data source: CIMIS, NASS

Trends in Dry and Wet Spells



Feng and Hu, 2004, J Theor Appl Clim

United States

Managed Agricultural Landscapes in California



Change in Irrigated Lands

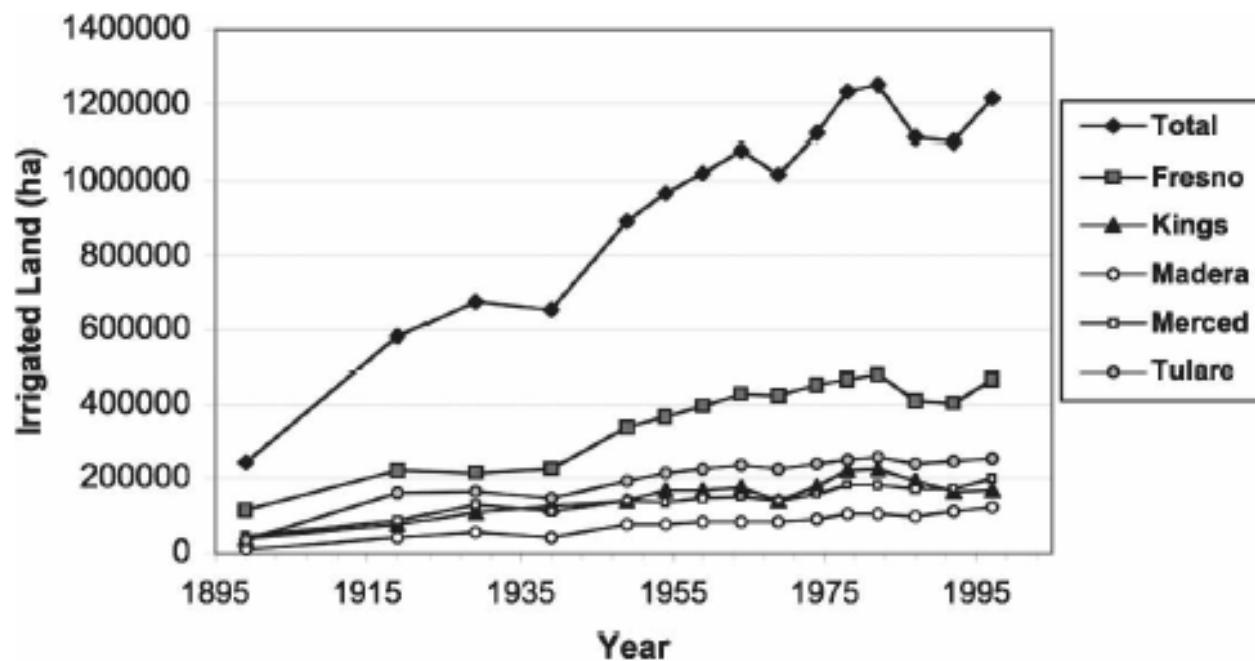
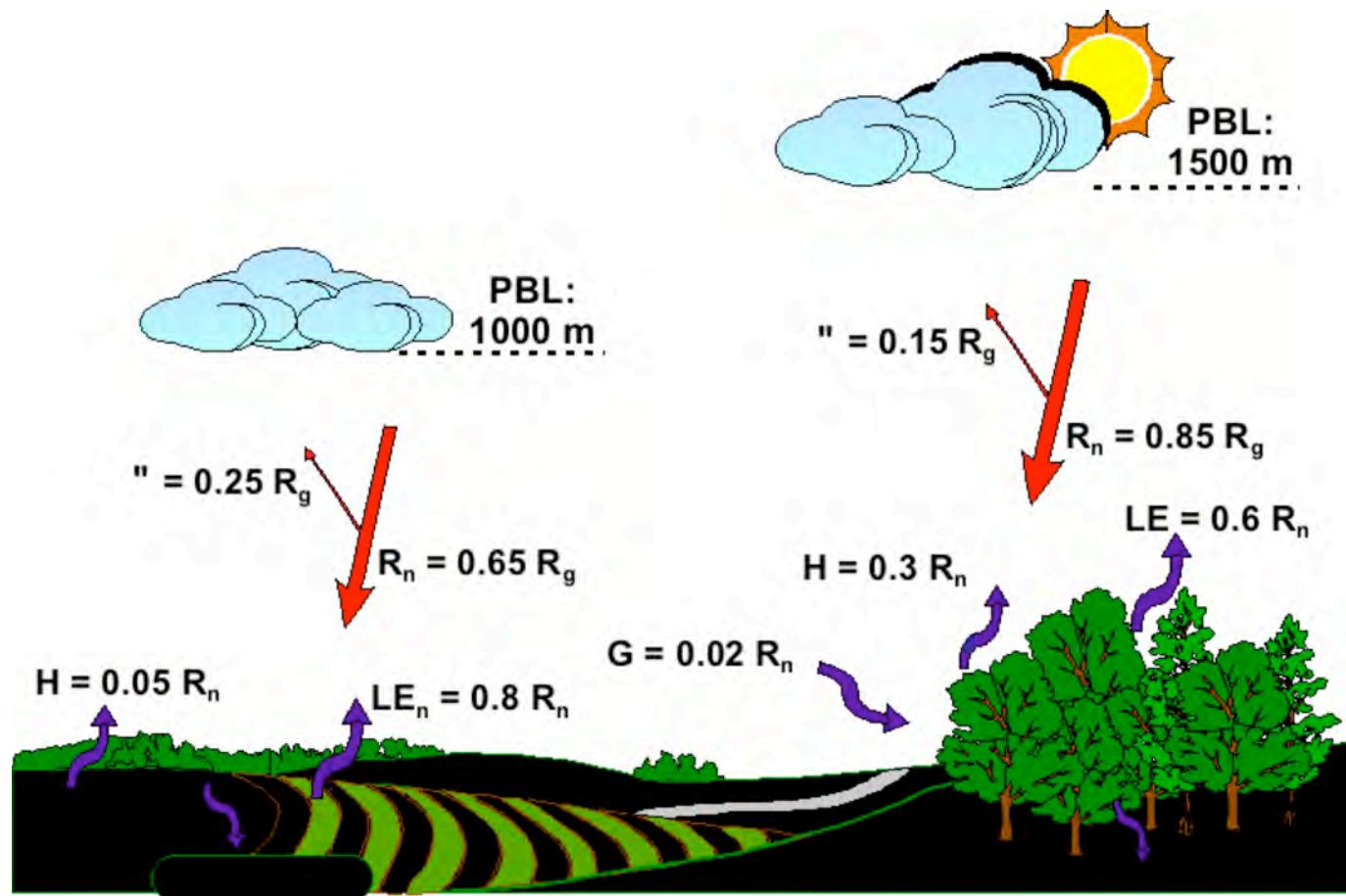


FIG. 1. Land area on which irrigation was applied in five counties utilized in this study. Mariposa County had negligible land under irrigation.

Agriculture, Land use Change and Climate

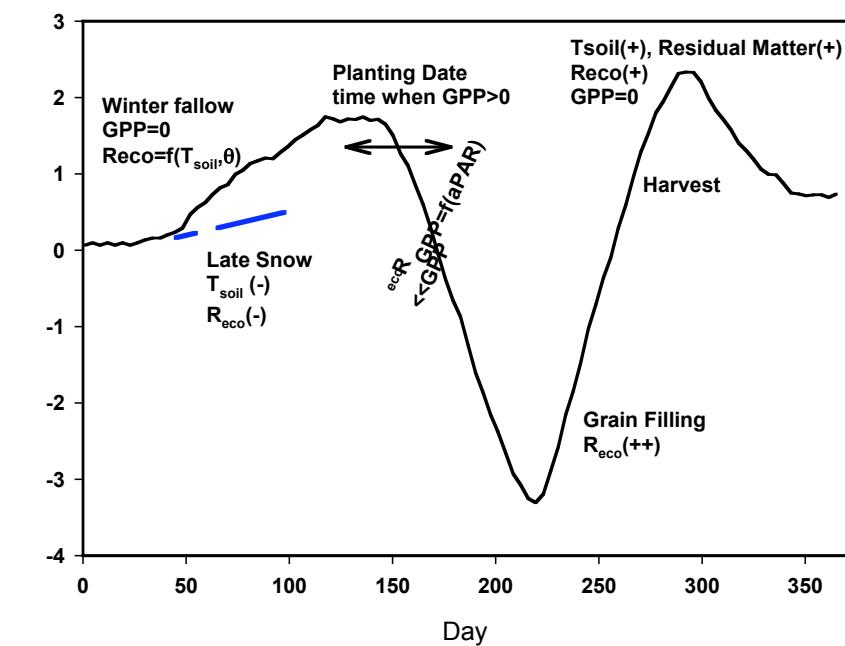
- Albedo
- Energy Partitioning into Heat and Evaporation
 - Leaf Area Index
 - Surface Wetness
 - Surface Conductance
- Carbon Uptake and Respiration
- Climate
 - Maximum and Minimum Air Temperature
 - Humidity

Role of Agriculture in the Climate System

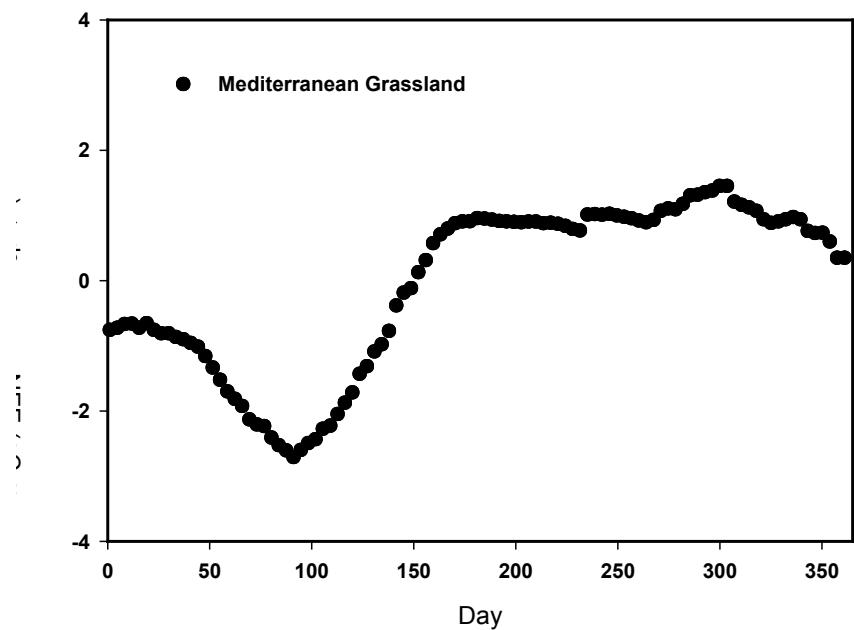


Role of Agriculture in Carbon Cycle

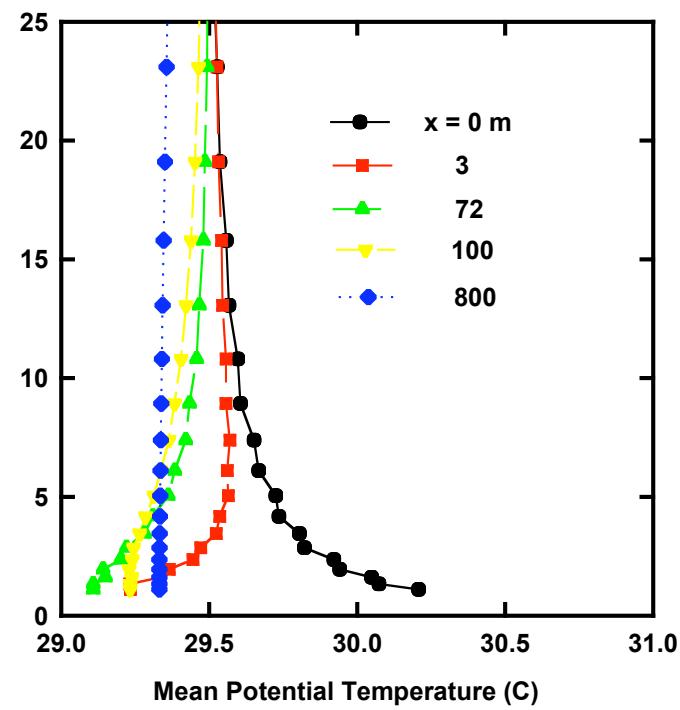
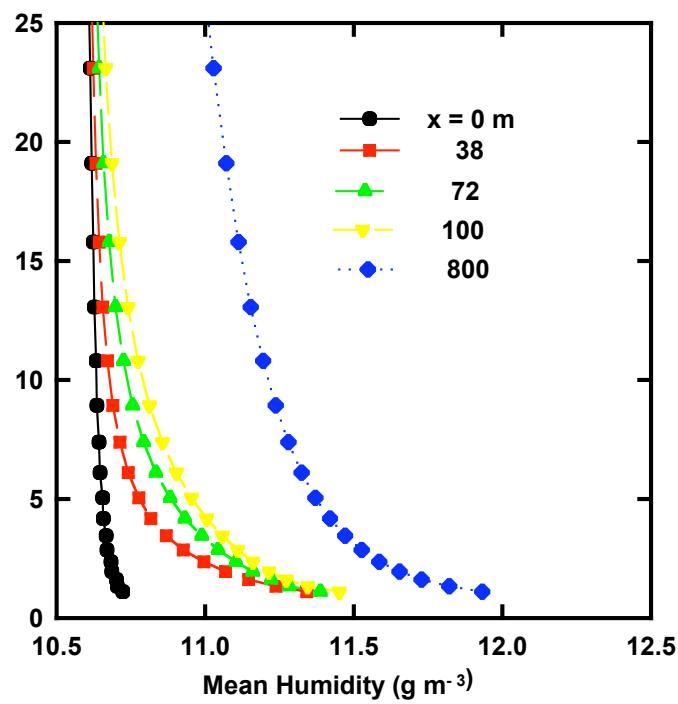
Agricultural Crop



Grasslands

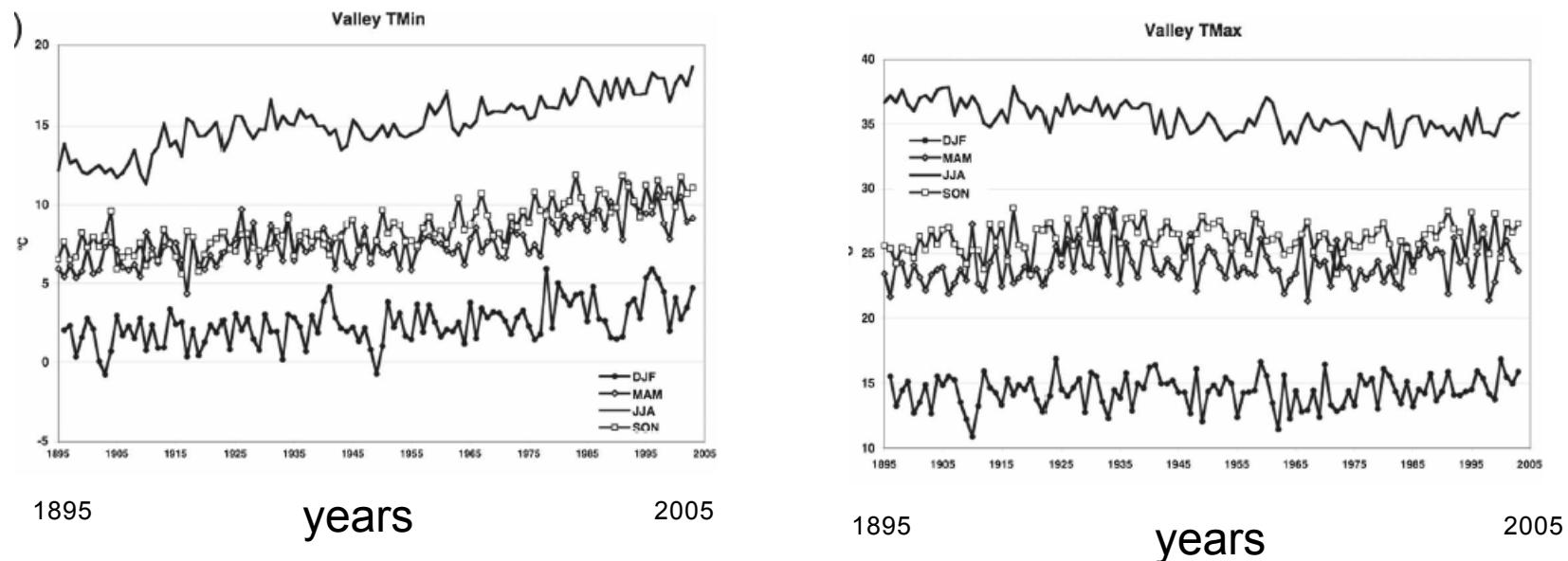


Humidity/Temperature Transition, Desert to Irrigated Crop



Baldocchi and Rao, BLM 1996

Central Valley Trends in Minimum Temperature: Partially Attributed to Land Use Change

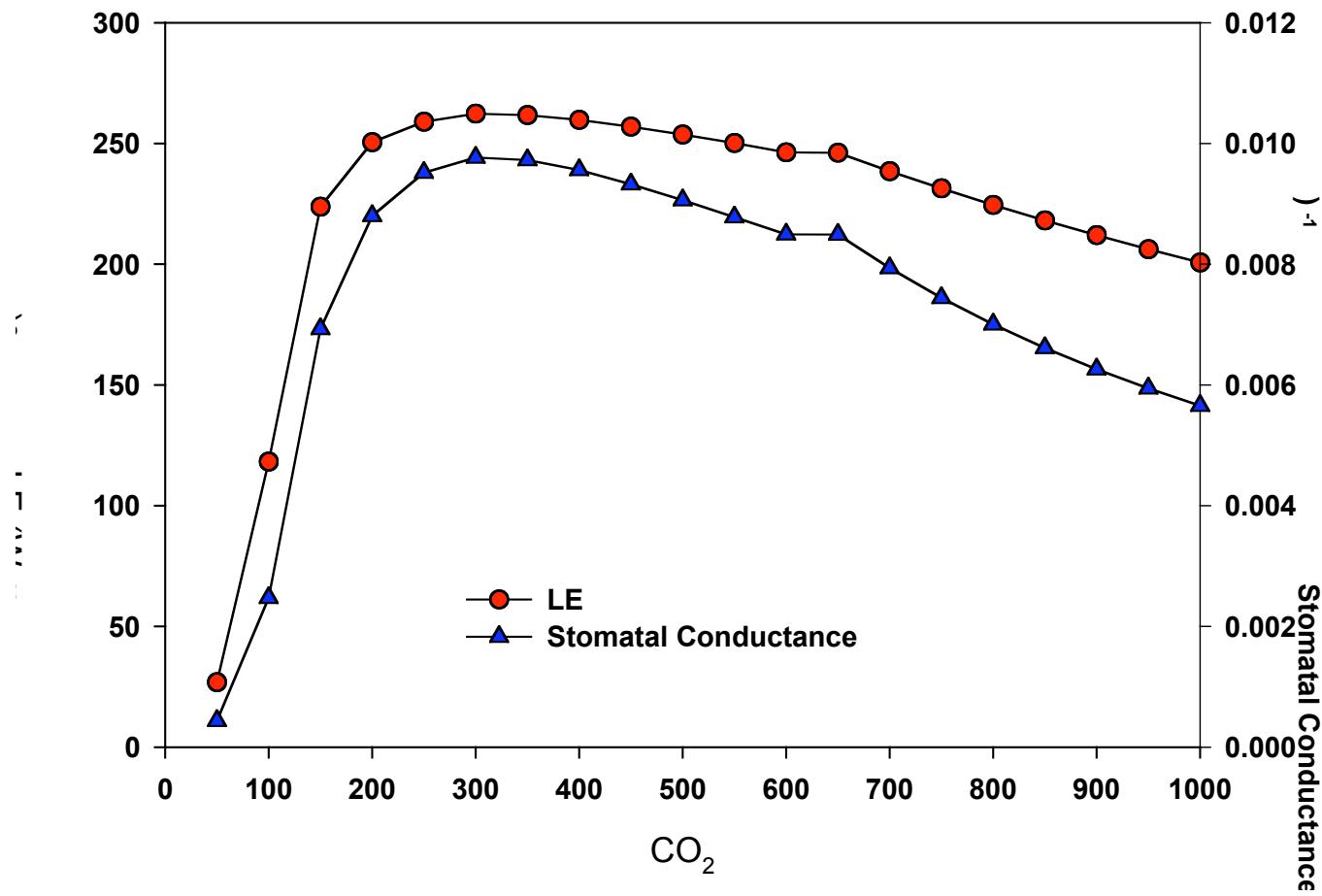


- Moisture, from Irrigation, increases downward Longwave energy at night
- Evaporative cooling offsets daytime warming trend

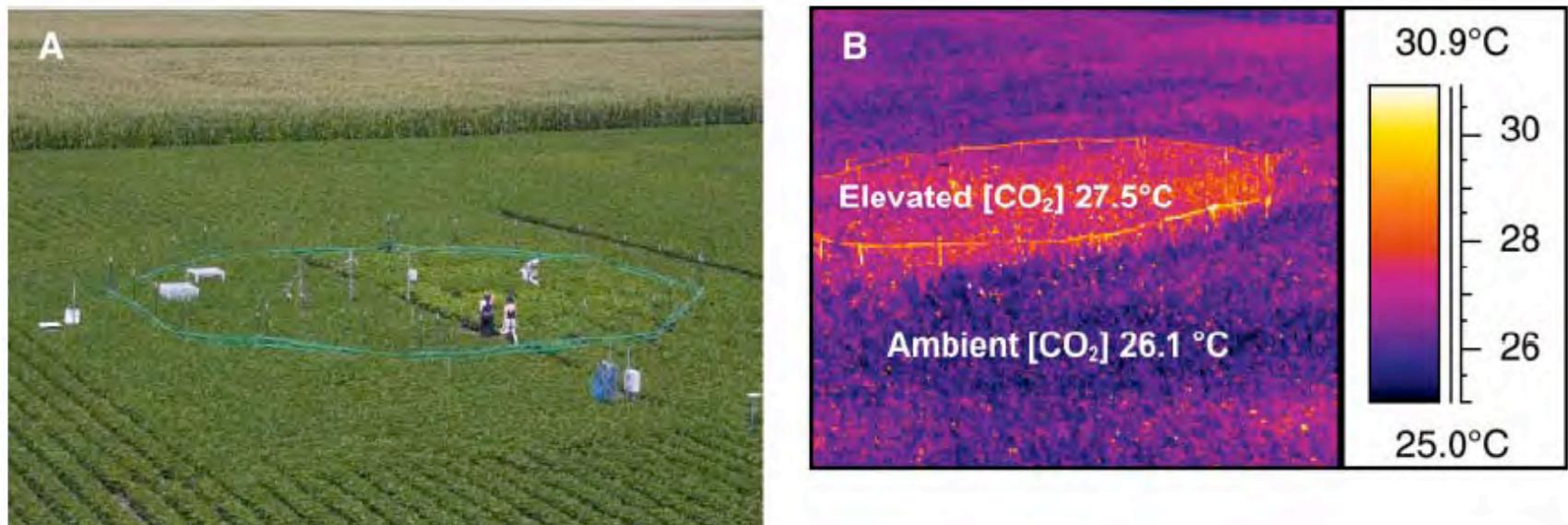
Elevated CO₂

- Pros
 - Increases Photosynthesis, short-term
 - Promotes Stomatal Closure
 - Increases Water Use Efficiency
- Cons
 - Down-regulation in Photosynthesis, long-term

Leaf Transpiration and Elevated CO₂

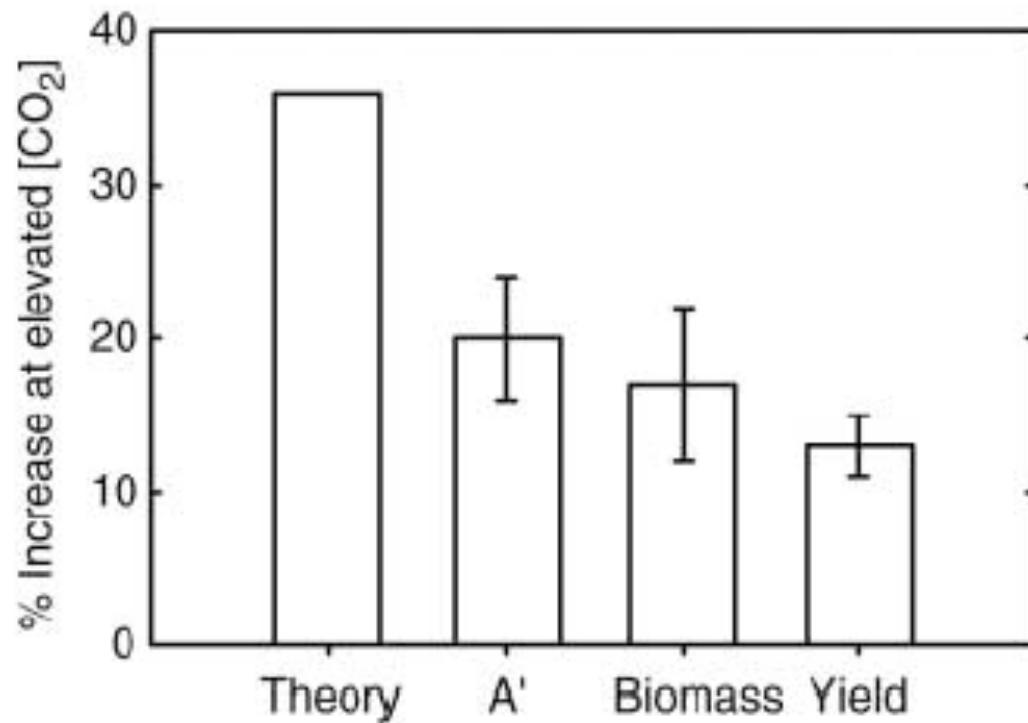


CO_2 and Crop Temperature: Induced Stomatal Closure Increases Surface Temperature



Long et al., 2006 Science

DownRegulation of Photosynthesis and Yield Occurs with Time



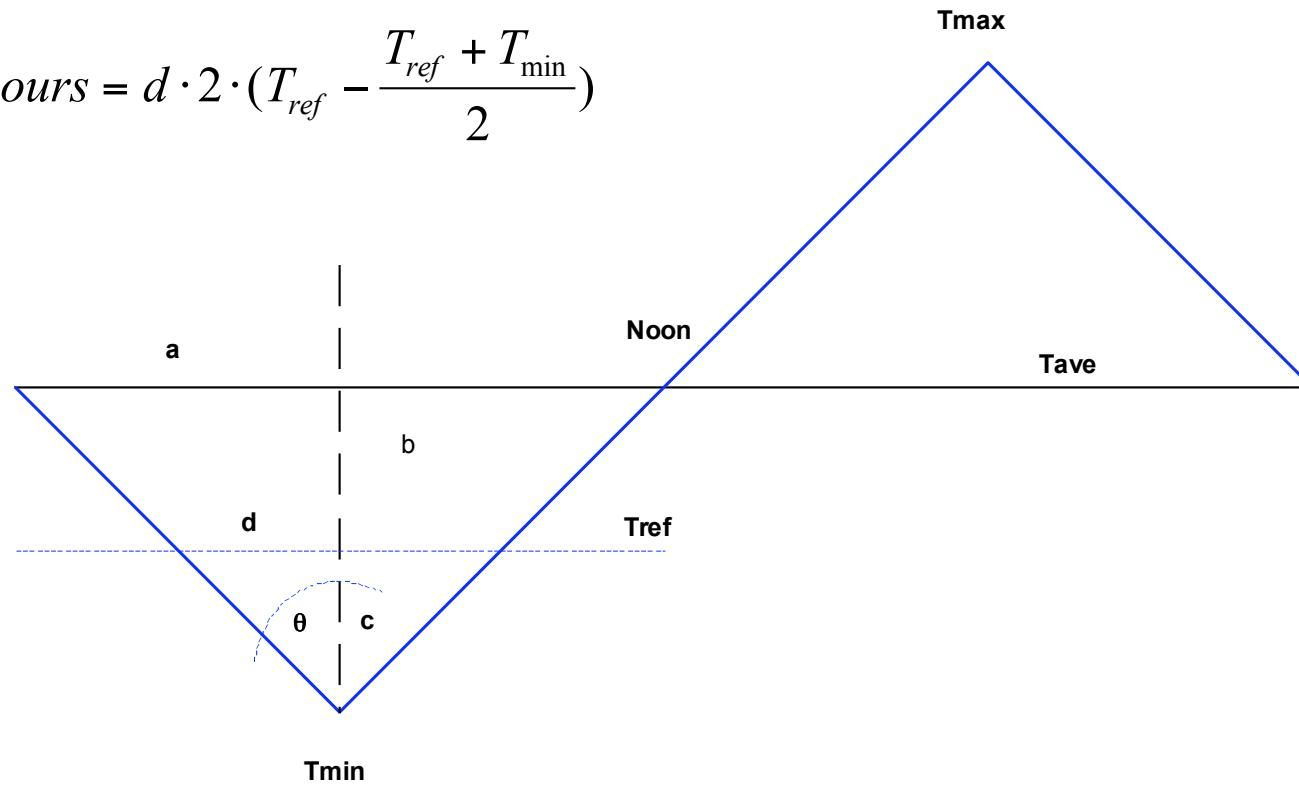
Long et al 2006 Science

Case Study

- Trends in Winter Dormancy in the CA Fruit Growing Region
- Data Sources
 - CIMIS, Hourly, from 1980s
 - National Climate Center Coop, Max-Min, from 1930s

Estimating Winter Chill

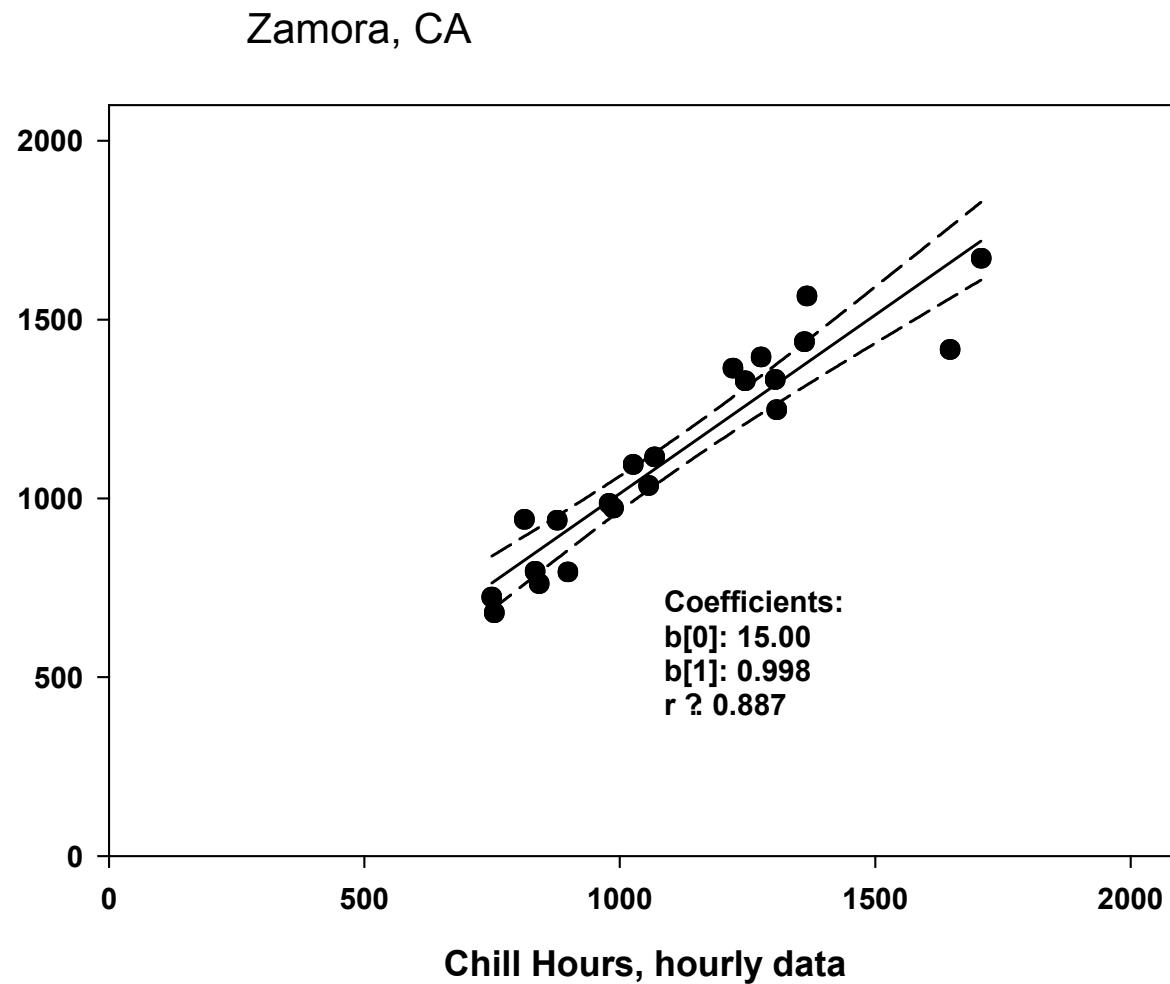
$$\sum chillhours = d \cdot 2 \cdot \left(T_{ref} - \frac{T_{ref} + T_{min}}{2} \right)$$



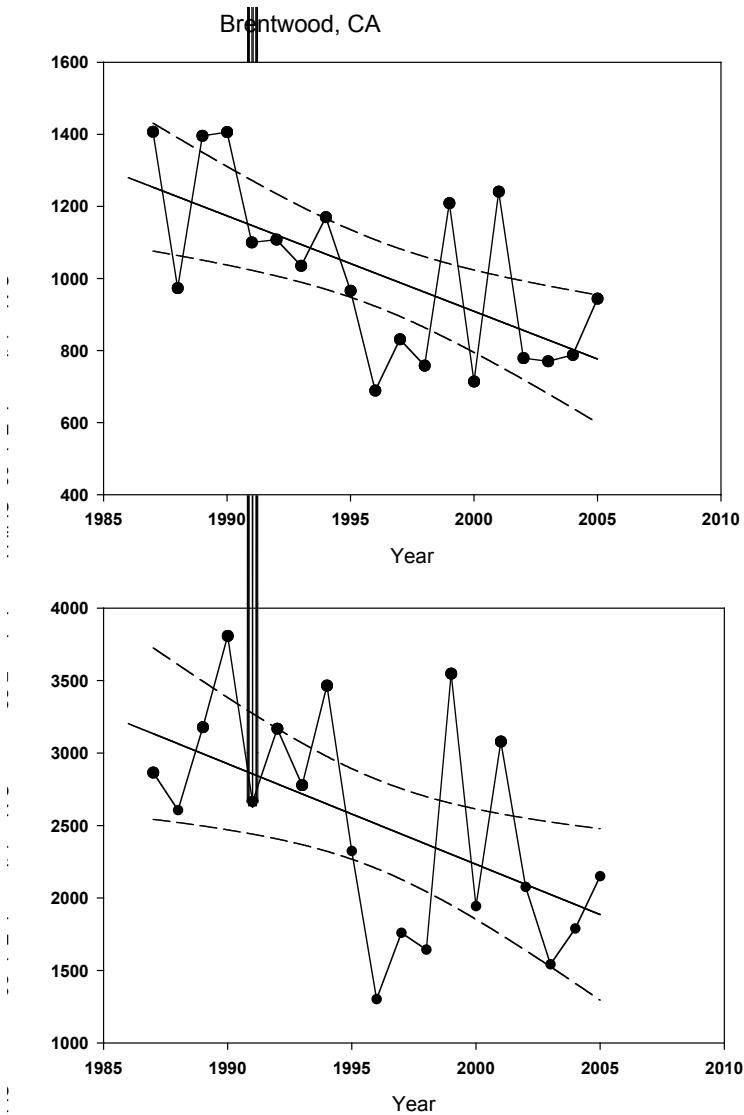
$$d = \frac{chillhours}{2} = \tan \theta \cdot (T_{ref} - T_{min})$$

$$\tan \theta = \frac{a}{b} = \frac{6hr}{T_{ave} - T_{min}}$$

Testing Chill Hour Sums with Daily and Hourly Data on Annual Basis



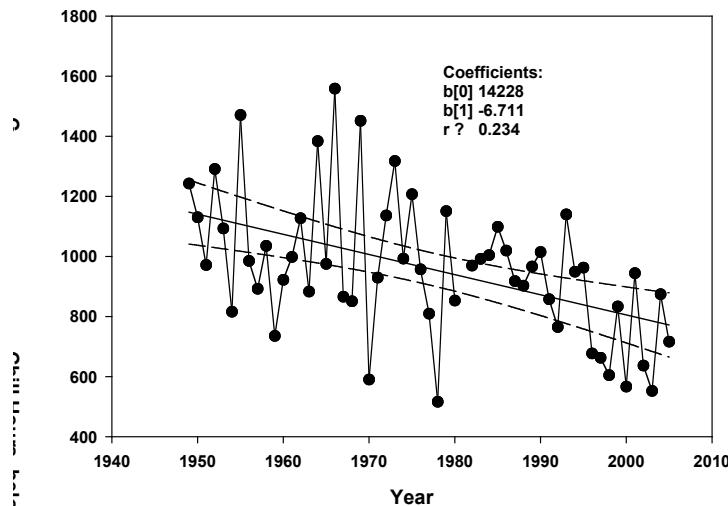
Downward Trend in Chill Hours near Brentwood, East Contra Costa



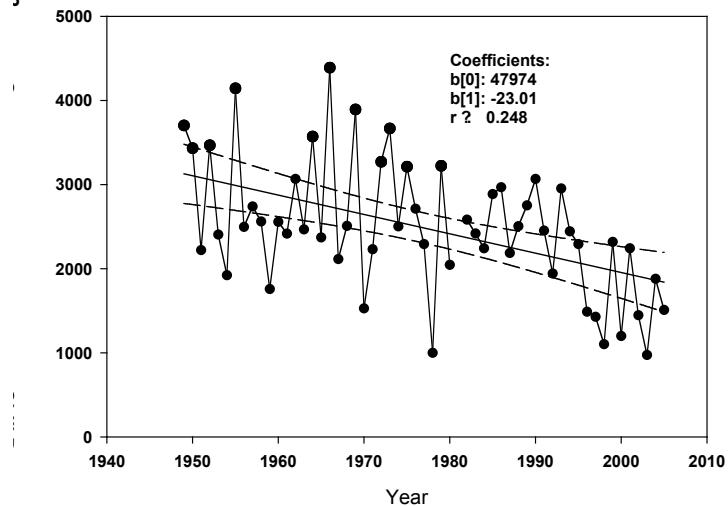
20 year record,
CIMIS Data

Downward Trend in Chill Hours near Orland, northern Sac Valley

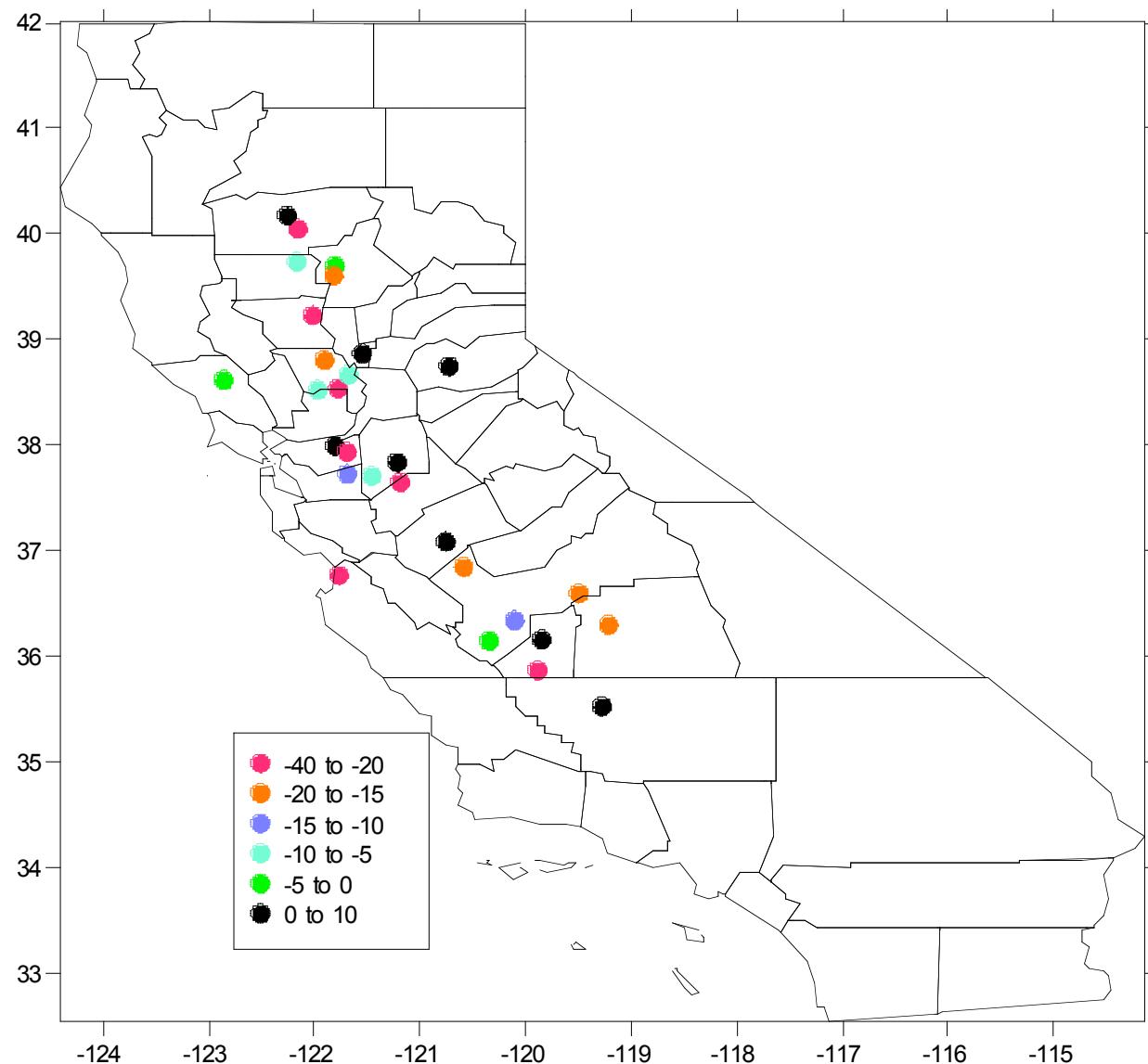
Orland, Ca



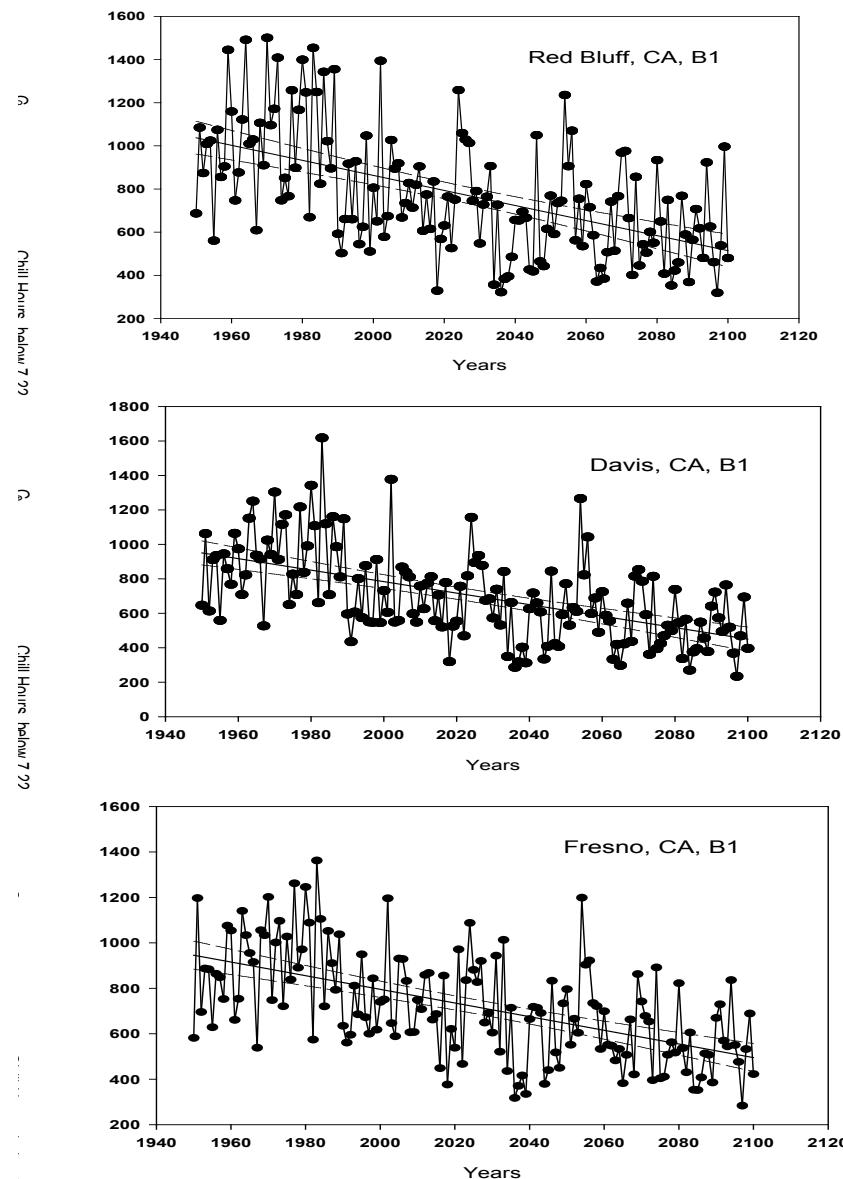
50+ year Record,
Coop Data



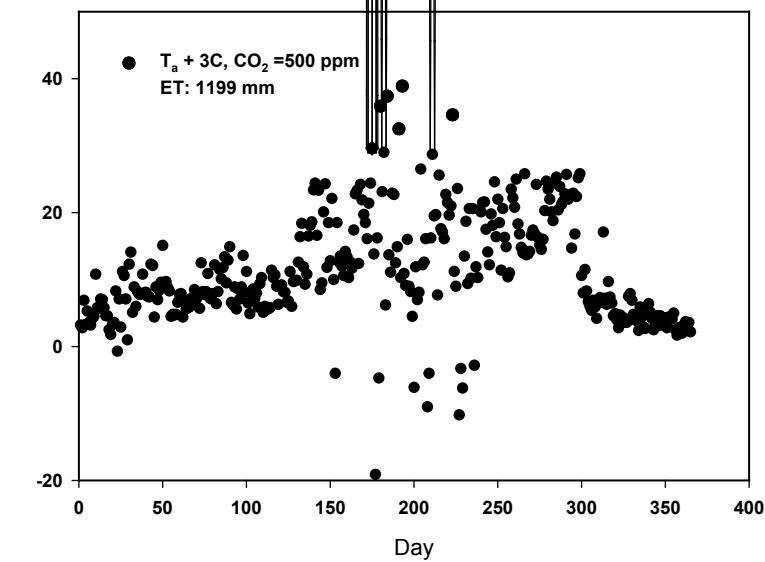
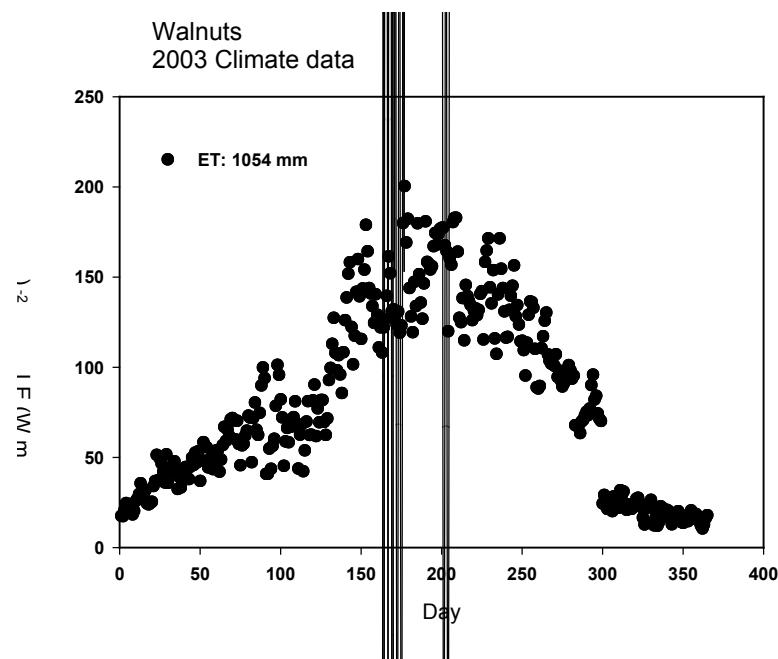
Trends in Winter Chill Hour Accumulation (hours per year)
Nov-Mar, 0 to 7.22 C



Projected Trends in Winter Chill



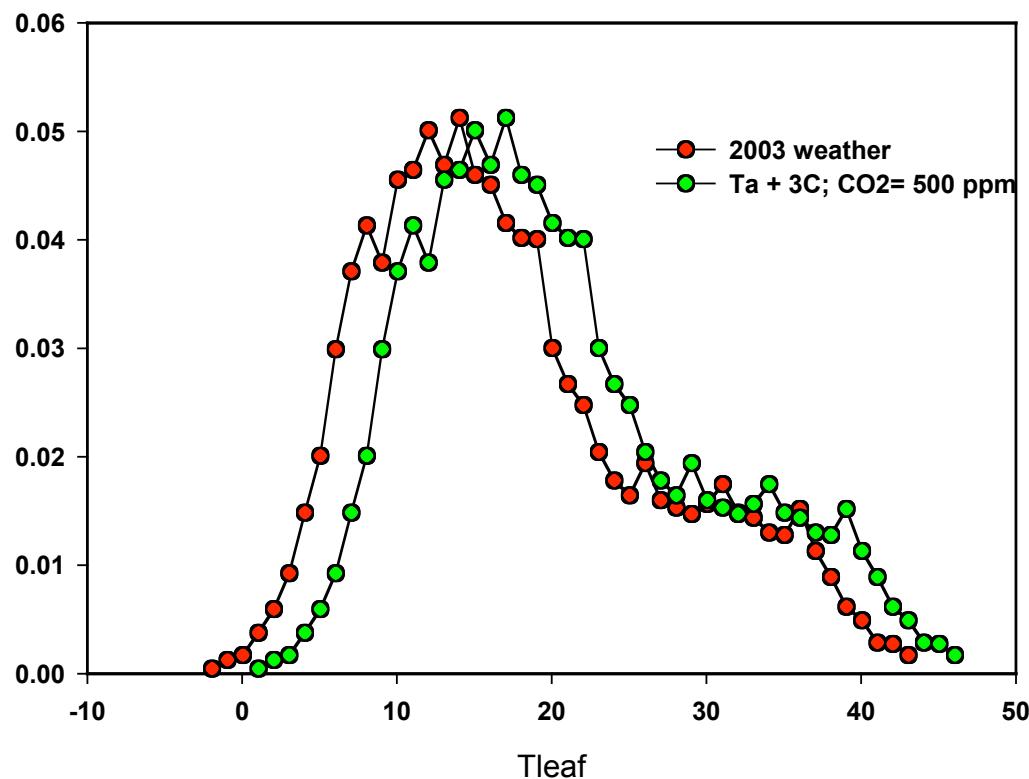
Walnut Water Use



Potential Change in the Incidence of Sunburn



Walnuts
Sunlit leaves



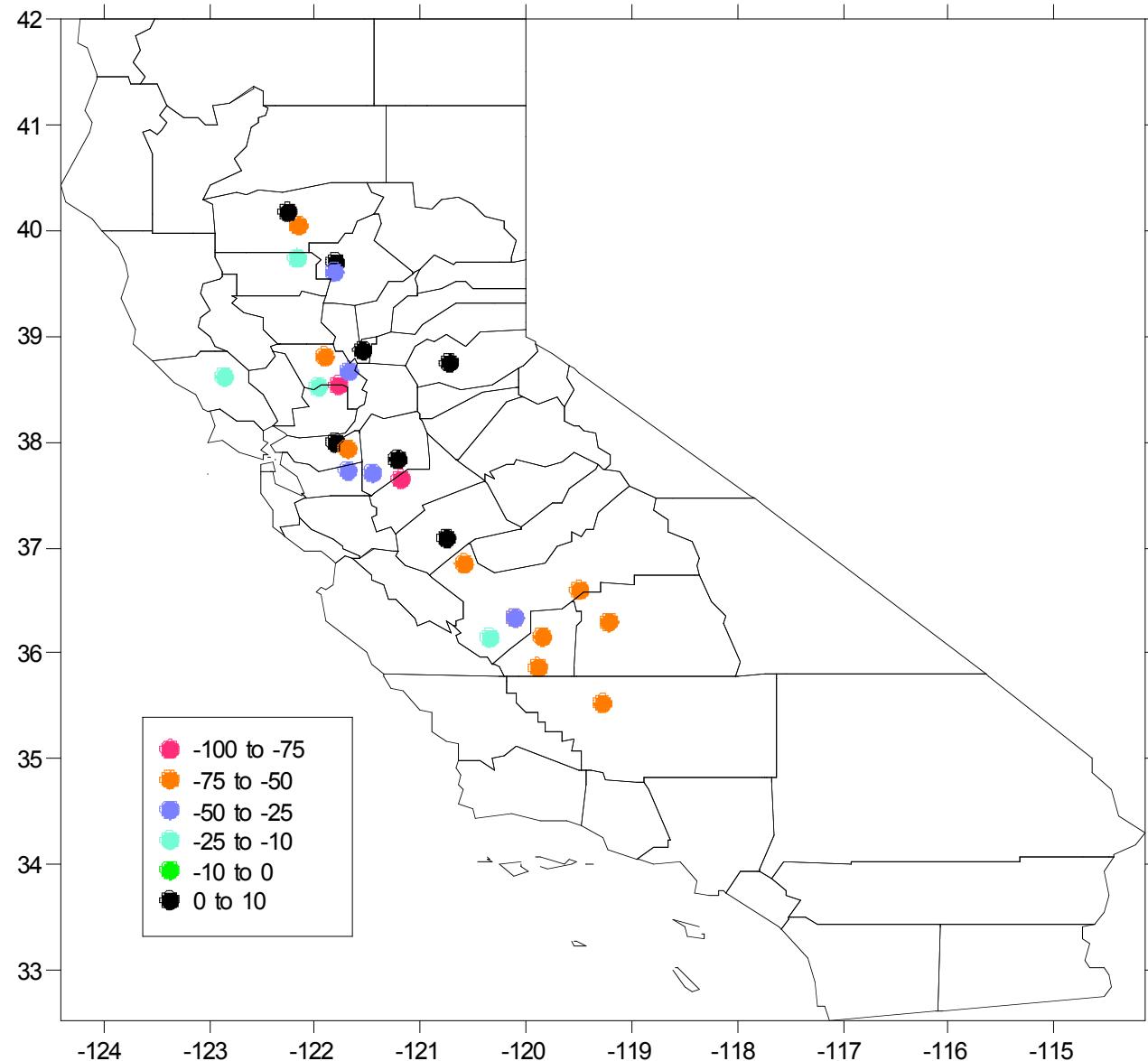
Solutions

- Irrigation scheduling and soil moisture management
- Proper choice of Crops and Environment
- Mulches and increased soil organic matter to reduce soil evaporation and runoff
- Precision agriculture and drip irrigation
- Changes in crops, timing and rotation
- Crop Breeding for water use efficiency, reduced dormancy
- Use of Reflectants to Increase albedo and reduce heat stress

Summary

- Climate Change is in Motion in California
 - Due to a combination of Rising Greenhouse Gases and Landuse Change
- Long term production of valuable fruit crops is vulnerable due to trends in reduced winter chill
 - The future trends may not be linear, but could accelerate if winter fog patterns change
- Breeding programs are needed to produce cultivars that require less winter chill

Trends in Winter Chill Degree Hours Accumulation (degree-hours per year)
Nov-Mar, 0 to 7.22 C



Daily Basis

Zamora, CA

